Non-Drilling Fluid Discharges: Temperature Analysis

For non-drilling fluid discharges, which include significant flow volumes of non-contact cooling water, EPA analyzed the dilution of the discharges and the temperature impact at a range of distances from the point of discharge. EPA used a generic and conservative model to estimate dilution for 100 discharge scenarios (cite to memo). The model is conservative, because it does not account for discharge momentum-induced ("jet") mixing at the outfall port, which generates substantial dilution for high-flow discharges. Additionally, high-flow discharges represent the worst case scenarios.

The scenarios span the range of expected effluent flows, discharge depths, and current speeds, including Shell's proposed discharge volume for non-contact cooling water of approximately 45,000 bbl/day and an even higher 113,000 bbl/day.

Dilution

The dilution results for the first 25 scenarios from Table X in the technical memo are excerpted below. This excerpt includes the worst case scenario (Case 104) and other shallow water discharges that are predicted to have the lowest dilution of the 100 cases. While the model evaluated discharges at water depths of 2 meters, the Beaufort general permit prohibits all discharges in areas where the water depth is less than 5 meters.

Table X : Excerpt of Dilution Estimation Results for Non-Drilling Mud Discharges

Case ID	Effective Water Depth (m)	Current Speed (m/sec)	Discharge Rate (bbl/day)	Discharge Rate (cms)	Dilution Factor at 10 m	Dilution Factor at 100 m	Dilution Factor at 1000 m
101	2	0.02	200	0.00037	121.8	385.3	1218.0
102	2	0.02	2250	0.00414	10.8	34.3	108.3
103	2	0.02	4500	0.00828	5.4	17.1	54.2
104	2	0.02	45000	0.08280	na	1.7	5.4
105	2	0.02	113000	0.20790	na	na	2.2
106	2	0.10	200	0.00037	609.2	1927.0	6092.0
107	2	0.10	2250	0.00414	54.2	171.3	541.5
108	2	0.10	4500	0.00828	27.1	85.6	270.8
109	2	0.10	45000	0.08280	2.7	8.6	27.1
110	2	0.10	113000	0.20790	1.1	3.4	10.8
111	2	0.30	200	0.00037	1828.0	5780.0	18280.0
112	2	0.30	2250	0.00414	162.5	513.8	1625.0
113	2	0.30	4500	0.00828	81.2	256.9	812.3
114	2	0.30	45000	0.08280	8.1	25.7	81.2
115	2	0.30	113000	0.20790	3.2	10.2	32.3
116	2	0.40	200	0.00037	2437.0	7706.0	24370.0
117	2	0.40	2250	0.00414	216.6	685.0	2166.0
118	2	0.40	4500	0.00828	108.3	342.5	1083.0
119	2	0.40	45000	0.08280	10.8	34.3	108.3
120	2	0.40	113000	0.20790	4.3	13.6	43.1
121	5	0.02	200	0.00037	481.6	1523.0	4816.0
122	5	0.02	2250	0.00414	42.8	135.4	428.1

123	5	0.02	4500	0.00828	21.4	67.7	214.1
124	5	0.02	45000	0.08280	2.1	6.8	21.4
125	5	0.02	113000	0.20790	na	2.7	8.5

The results show a wide range of dilution factors based on various discharge flows, depths and current speeds. At 100 meters distance from the discharge point, dilution factors range from 1.7:1 (case 104) to over 900,000:1 (case 196).

Temperature Impact

Information obtained from Shell indicated that the temperature increase from the non-contact cooling water discharge is 1.4 deg C greater than ambient temperatures of the Beaufort Sea. For purposes of the model, EPA used a value of 1.5 deg C to evaluate the potential temperature impacts from the discharge.

The Alaska Water Quality Standard for temperature for marine water uses (Water Supply, Aquaculture) state that the discharge “may not cause the weekly average temperature to increase more than 1□C. The maximum rate of change may not exceed 0.5□C per hour normal daily temperature cycles may not be altered in amplitude or frequency.”

The temperature impact for a specific scenario is calculated by dividing the assumed temperature differential between effluent and ambient temperature (1.5 deg C) by the dilution in Table X above for the given case.

The increase in ambient temperature due to the discharge is shown in Table Y (same subset of 25 cases as Table X above). The predicted increase in temperature at 100 meters ranges from 0.000002 deg C to 0.88 deg C. Therefore, temperatures are expected to achieve the first component of the Alaska Water Quality criterion of 1.0 deg C at 100 meters for all 100 cases.

Table Y : Temperature Impact from Non-Drilling Mud Discharge for Effluent Temperature 1.5 Deg C above Ambient

Case ID	Effective Water Depth (m)	Curren t Speed (m/sec)	Discharg e Rate (bbl/day)	Discharge Rate (cms)	Temp Impact at 10 m	Temp Impact at 100 m	Temp Impact at 1000 m
					deg C	deg C	deg C
101	2	0.02	200	0.00037	0.01	0.00	0.00
102	2	0.02	2250	0.00414	0.14	0.04	0.01
103	2	0.02	4500	0.00828	0.28	0.09	0.03
104	2	0.02	45000	0.0828	na	0.88	0.28
105	2	0.02	113000	0.2079	na	na	0.68
106	2	0.1	200	0.00037	0.00	0.00	0.00
107	2	0.1	2250	0.00414	0.03	0.01	0.00

108	2	0.1	4500	0.00828	0.06	0.02	0.01
109	2	0.1	45000	0.0828	0.56	0.17	0.06
110	2	0.1	113000	0.2079	1.36	0.44	0.14
111	2	0.3	200	0.00037	0.00	0.00	0.00
112	2	0.3	2250	0.00414	0.01	0.00	0.00
113	2	0.3	4500	0.00828	0.02	0.01	0.00
114	2	0.3	45000	0.0828	0.19	0.06	0.02
115	2	0.3	113000	0.2079	0.47	0.15	0.05
116	2	0.4	200	0.00037	0.00	0.00	0.00
117	2	0.4	2250	0.00414	0.01	0.00	0.00
118	2	0.4	4500	0.00828	0.01	0.00	0.00
119	2	0.4	45000	0.0828	0.14	0.04	0.01
120	2	0.4	113000	0.2079	0.35	0.11	0.03
121	5	0.02	200	0.00037	0.00	0.00	0.00
122	5	0.02	2250	0.00414	0.04	0.01	0.00
123	5	0.02	4500	0.00828	0.07	0.02	0.01
124	5	0.02	45000	0.0828	0.71	0.22	0.07
125	5	0.02	113000	0.2079	na	0.56	0.18

These results also indicate a very low probability of exceeding hourly change criterion of 0.5 deg C. Only two of 100 cases have an estimated impact greater than 0.5 deg C at 100 m (cases 104 and case 125) and these include the conditions under which the model is most conservative (i.e., overestimates impact). However, as noted above, because the Beaufort general permit prohibits all discharges in water depths less than 5 meters, as measured from mean lower low water, case 104 would never occur. Case 125 includes a 0.06 deg C increase above the criterion and would occur at the maximum discharge rate within shallow waters and at an assumed lowest current speed.

A number of combinations with high discharge rates yielded dilution factors less than 1, identified by "na" in the table. This indicates that the combination of parameters entering the calculation produce an unrealizable result as well as indicating that the assumptions of the ambient mixing model are not appropriate. Actual discharges having these high flows likely has significant jet induced mixing and should be analyzed using discharge specific parameters including discharge port diameter, orientation, and depth of discharge.